Exfiltration Trenches

A. From Paragraph 5.4 of the *Basis of Review*:

"5.4 Underground Exfiltration Systems -

(a) Systems shall be designed for the retention volumes specified in Section 5.2.1 for retention systems, exfiltrated over one hour for retention purposes, prior to overflow, and based on test data for the site. (Note: such systems should not be proposed for projects to be operated by entities other than single owners or entities with full time maintenance staff.)

(b) A safety factor of two or more shall be applied to the design to allow for geological uncertainties.

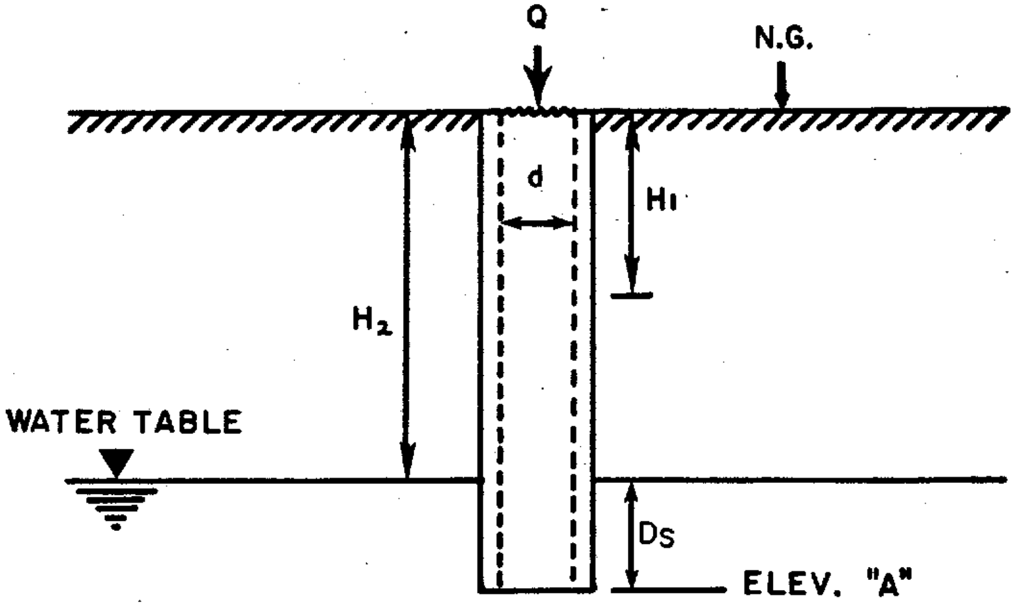
(c) A dry system is one with the pipe invert at or above the average wet season water table."

Paragraph 5.2.2(a) is the requirement that projects with commercial or industrial zoning must provide dry pretreatment. Obviously, a project which falls into this category and is being designed to meet the criteria by using trench must have the pipe invert at or above the average wet season water table. It is also a requirement that no gravity discharge from the trench system be allowed below the elevation of the top of the perforated pipe.

B. Three field test procedures for determining hydraulic conductivity will be described next. The first is the usual constant head test. The second is the falling-head test, which may be utilized in areas of excellent percolation, and when difficulty "keeping the hole filled" is encountered. The third is a standard test used by the Florida Department of Transportation.

The engineer is cautioned that, when tests are conducted, site-specific characteristics, such as soil type, geology and hydrologic conditions must be factored into the field test methodology. Actual hydrologic conditions under which the exfiltration trench would be expected to perform must also be considered.

USUAL OPEN - HOLE TEST



$$K = \frac{4Q}{\pi d(2H_2^2 + 4H_2 D_S + H_2 d)}$$

K = HYDRAULIC CONDUCTIVITY (CFS/FT.^{2}- FT. HEAD)

Q = "STABILIZED" FLOW RATE (CFS)

d = DIAMETER OF TEST HOLE (FEET)

H_2 = DEPTH TO WATER TABLE (FEET)

D_S = SATURATED HOLE DEPTH (FEET)

ELEV. "A" = PROPOSED TRENCH BOTTOM ELEV.
H_1 = AVERAGE HEAD ON UNSATURATED HOLE SURFACE (FT. HEAD)

Figure F-1

2. Falling-head Test

The falling-head test is an open-hole test which is either uncased or cased with fully-perforated casing. The procedure is described as follows:

a. Auger a 6 to 9 inch diameter hole to a depth below the ground surface equivalent to the design depth of the trench (usually 4 to 6 feet).

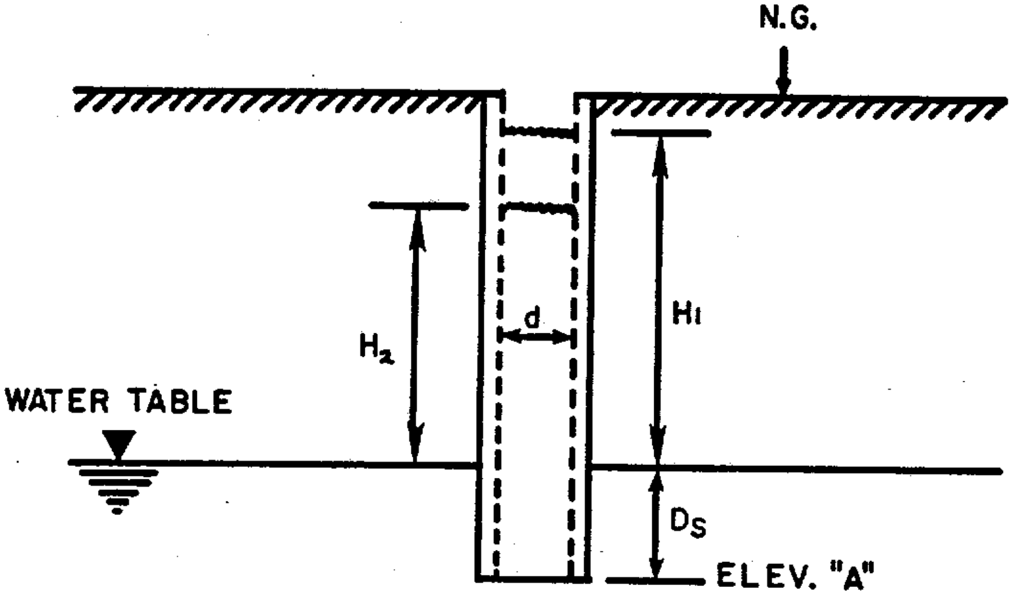
b. Record the distance from the ground surface to the water table prior to the addition of test water.

c. If hole walls are unstable, lower screen or fully-perforated casing into the hole.

d. Fill hole with water and maintain water level at ground surface. Cease adding water and measure the water level versus elapsed time in equal time increments, usually in 15-second increments. Continue measuring water level until it has dropped at least half the distance to the water table.

Figure F-2 shows a cross section of the test hole with a formula relating the hydraulic conductivity to the field information.

FALLING - HEAD OPEN - HOLE TEST



$$K = \frac{d \ln(H_1/H_2)}{(2H_1+2H_2+4D_S+d)(t_2-t_1)}$$

K = HYDRAULIC CONDUCTIVITY (CFS/FT.^{2}-FT. HEAD)

d = DIAMETER OF TEST HOLE (FEET)

H_1 = HEIGHT OF WATER IN HOLE ABOVE WATER TABLE AT TIME, t_1

H_2 = HEIGHT OF WATER IN HOLE ABOVE WATER TABLE AT TIME, t_2

D_S = SATURATED HOLE DEPTH (FEET)

ELEV. "A" = PROPOSED TRENCH BOTTOM ELEV. (FT.-NGVD)

t_1, t_2 = TIME, SECONDS

Figure F-2

3. D.O.T. Standard Test

The Florida Department of Transportation utilizes a standard test for design of seepage trenches in conjunction with highway projects. The D.O.T. test procedure is as follows:

Auger a 7 inch diameter hole to a depth of 10 feet below normal ground surface.

Record distance from ground surface to water table prior to addition of test water.

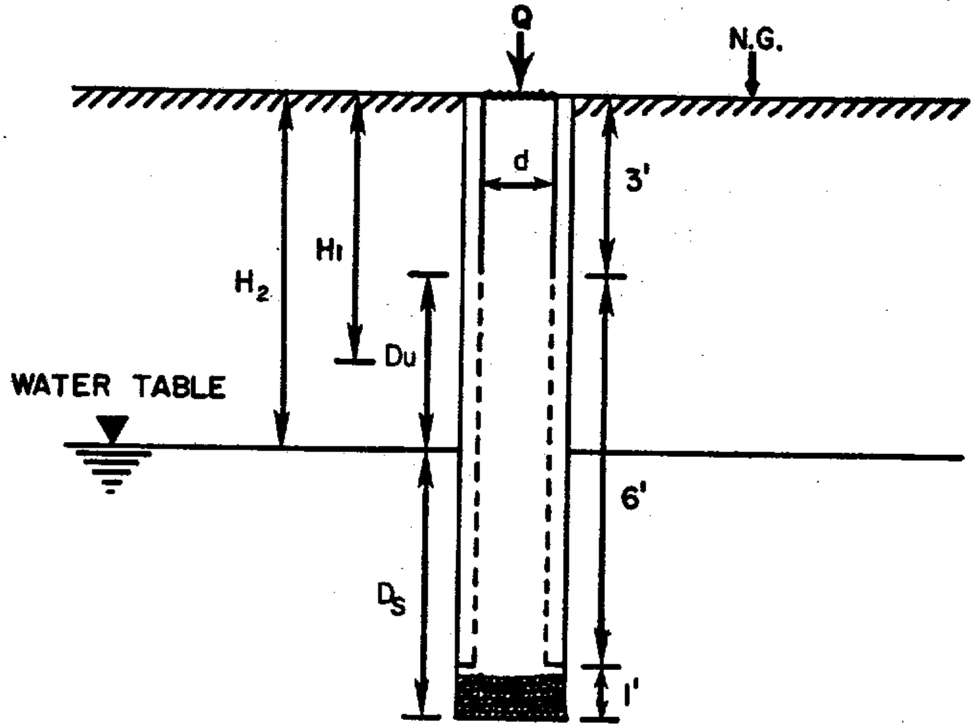
Pour 1/8 cubic foot of 1/2 inch diameter gravel in hole to prevent scouring.

Lower a 6 inch diameter perforated 10 gauge aluminum casing into hole. Casing to be 9 feet in length with perforations in the bottom 6 feet of the casing.

5. Fill hole with water and maintain water level at ground surface. Record rate of pumping in g.p.m. giving direct readings from water meter at fixed intervals. Use one minute intervals or greater, depending on the hydraulic conductivity of the soil. Continue recording rate of pumping for 10 minutes following the stabilization of the recorded pumping rate.

A schematic cross section of the D.O.T. test hole is shown in Figure F-3 with a formula which relates the hydraulic conductivity to the field data. The D.O.T. does not recommend utilization of seepage trenches in areas where this test yields less than 6 g.p.m.

D.O.T. STANDARD TEST



FOR $H_2 > 3.0$ FEET:

$$K = \frac{4Q}{\pi(20.25 H_2 - H_2^2 - 9)}$$

K = HYDRAULIC CONDUCTIVITY (CFS/FT.^{2} - FT. HEAD)

Q = "STABILIZED" FLOW RATE (CFS)

d = DIAMETER OF TEST HOLE (FEET)

Du = UNSATURATED HOLE DEPTH (FEET)

D_S = SATURATED HOLE DEPTH (FEET)

H_1 = AVERAGE HEAD ON UNSATURATED HOLE SURFACE (FT. HEAD)

H_2 = DEPTH TO WATER TABLE (FEET).

FOR $H_2 \leq 3.0$ FEET:

$$K = \frac{Q}{11.192 H_2}$$

Figure F-3

4. Analysis of Test Data

In this section actual test data which was compiled during a field test of the "usual" case will be described and the soil permeability calculated. The test was performed on a piece of property in Broward County, Florida. The test hole was 9 inches in diameter augered to a depth of 6 feet. A 9 inch diameter by 72 inch long perforated casing was set in the hole. The depth to the water table prior to introduction of test water was 5.3 feet below the ground. The field data collected during the test are shown in Table F-1.

Taking the total flow into the test hole during the 75 minute test period and dividing by 75 minutes, since there was no significant variation in flow during the test, yields an average flow rate, Q, of 3.46 g.p.m., which is equivalent to 7.71×10^{-3} cfs. The diameter of the test hole, D, was 0.75 foot. The saturated hole depth, Ds, was equal to the depth of the hole, 6 feet, minus the depth to the water table, 5.3 feet, which is equal to 0.7 foot.

Utilizing the formula from Figure F-1:

$$K = \frac{4Q}{\pi \; d \; (2H_2^2 + 4H_2D_S + H_2d)}$$

$$K = \frac{4(7.71 \times 10^{-3})}{\pi \; (0.75)\;(2(5.3)^2 + 4(5.3)\;(0.7) + (5.3)\;(0.75))}$$

$$K = 1.75 \times 10^{-4} \text{ cfs/ft}^2\text{-ft. head}$$

TABLE F-1

BROWARD COUNTY - USUAL OPEN-HOLE TEST

Elapsed Time (Minutes)	Begin Meter Reading	End Meter Reading	Flow Gallons	Q (G.P.M.)
1	0.0	5.5	5.5	5.5
2	5.5	11.0	5.5	5.5
3	11.0	16.0	5.0	5.0
4	16.0	19.0	3.0	3.0
5	19.0	22.5	3.5	3.5
6	22.5	26.5	4.0	4.0
7	26.5	30.0	3.5	3.5
8	30.0	33.5	3.5	3.5
9	33.5	37.5	4.0	4.0
10	37.5	40.5	3.0	3.0
11	40.5	44.5	4.0	4.0
12	44.5	48.5	4.0	4.0
13	48.5	51.5	3.0	3.0
14	51.5	55.5	4.0	4.0
15	55.5	59.5	4.0	4.0
16	59.5	63.0	3.5	3.5
17	63.0	67.0	4.0	4.0
18	67.0	70.0	3.0	3.0
19	70.0	73.5	3.5	3.5
20	73.5	77.5	4.0	4.0
25	77.5	96.0	18.5	3.7
30	96.0	114.5	18.5	3.7
35	114.5	132.0	17.5	3.5
40	132.0	154.0	22.0	4.4
45	154.0	172.5	18.5	3.7
50	172.5	190.5	18.0	3.6
55	190.5	208.5	18.0	3.6
60	208.5	220.0	11.5	2.3
65	220.0	235.0	15.0	3.0
70	235.0	247.0	12.0	2.4
75	247.0	259.5	12.5	2.5

5. Design of Trenches

Since the first publication of *Volume IV, Permit Information Manual,* additional consideration has been given to the derivation of an acceptable exfiltration trench design formula. The latest development is shown on Figure F-4 along with the description of the appropriate parameters.

An example of the use of this formula with the data from the Broward County test site follows:

$$* \; L = \frac{V}{K(H_2W + 2H_2Du - Du^2 + 2H_2D_S) + (1.39 \times 10^{-4})WDu}$$

$V = 15$ Ac-In. **[Given]**

$K = 1.75 \times 10^{-4}$ CFS/FT^2 + FT HEAD

$H_2 = 5.0$ Feet (Design Condition)

$W = 4.0$ Feet

$Du = 2.5$ Feet

$D_S = 1.5$ Feet

$H = Du + D_S = 4.0$ Feet

Solving for L gives,

$L = 1389$ feet of 4′ x 4′ exfiltration trench.

Users of the formula should use as "V" the actual volume (in acre-inches) of water to be treated. Typical volumes are either 1" times the project area for water quality, or 2.5" times the percent impervious times the project area for water quality, or a volume necessary to provide dry pretreatment at certain commercial or industrial sites. "V" should not be adjusted by the user to account for either that exfiltration trench is a retention system (50% credit on volume to be treated) or that the formula has a safety factor of 2. Both those factors are already incorporated into the formula.

For those situations when either: (1) the saturated depth of trench is greater than the non-saturated depth of trench; or (2) the trench width is greater than two times the total trench depth, the proportional assumptions for flow out the trench bottom are probably not valid. A conservative design formula for use in these cases would be:

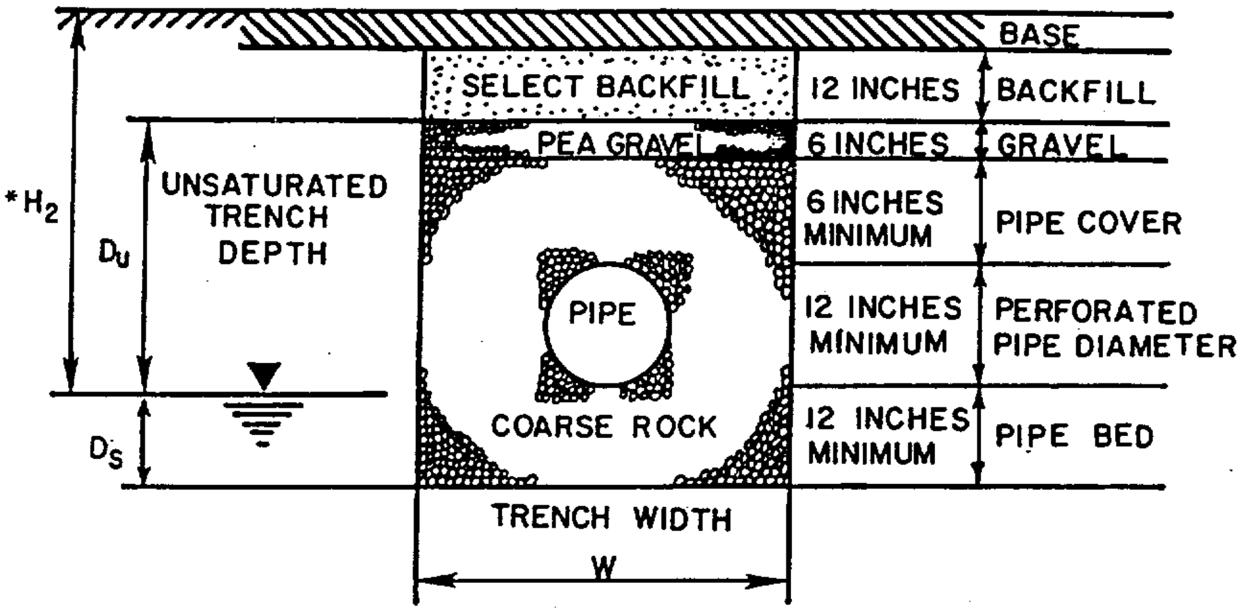
$$* L = \frac{V}{K(2H_2Du - Du^2 + 2H_2D_s) + (1.39 \times 10^{-4})WDu}$$

As with any design method, a good amount of engineering judgement must be applied for use on site-specific cases.

*** NOTE:**

The formulas derived to calculate exfiltration trench length are based on a one-hour time of exfiltration. This is representative of the majority of rainfall events being of small magnitude and short duration. Larger-magnitude and longer-duration storm events can affect the design by significantly changing the water table conditions assumed in the equation.

TYPICAL EXFILTRATION TRENCH



$$L = \frac{V}{K(H_2W + 2H_2D_u - D_u^2 + 2H_2D_S) + (1.39 \times 10^{-4})WD_u}$$

L = LENGTH OF TRENCH REQUIRED (FEET)

V = VOLUME TREATED (ACRE-INCHES)

W = TRENCH WIDTH (FEET)

K = HYDRAULIC CONDUCTIVITY (CFS/FT.^{2}-FT.HEAD)

*H_2 = DEPTH TO WATER TABLE (FEET)

D_u = NON-SATURATED TRENCH DEPTH (FEET)

D_S = SATURATED TRENCH DEPTH (FEET)

*The value of H_2 to be used in the equation is the effective head on the saturated surface. In most cases it will be less than the distance between the water table and the pavement elevation. For purposes of this example, the diagram above assumes no outfall from the exfiltration trench system.

Figure F-4